SPATIAL REPRESENTATIVENESS OF AIR QUALITY MONITORING STATIONS IN ITALY

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ABSTRACT

Supporting the design of the Italian Network of Special Purpose Monitoring Stations (Fig.1), a comprehensive study on **spatial representativeness of air quality monitoring sites** is presented, to be used in model validation and population exposure studies. **Different methodologies** are evaluated, in order to find out one or more fit-to-purpose approaches to spatial representativeness. In this work, we present preliminary results for 3 methods: one uses **station measurements and land cover data**, other two are based on air quality model simulations, using respectively **emissions variability** and **concentration time series**. Strengths and weaknesses of the methods are assessed and on-going developments are presented.

Fig. 1: Location of the special purpose stations.

METHOD 1: OBJECTIVE FACTORS (LAND COVER)

CONCEPT

An empirical relationship is assumed between land cover and concentrations recorded by air quality monitoring stations (widely used when insufficient data on emissions and meteorology and/or limited resources prevent a detailed representation of pollution processes).

PROCEDURE

Definition of the land cover polluting power indicator β (1), for the dependency of concentration on land cover.

The formulation is:

$$\beta = \log\left[1 + \left(\frac{\sum_i a_i \cdot n_{CLi}}{\sum_i n_{CLi}}\right)\right]$$

CL_i → class of land cover

nCL_i → fraction of the area corresponding to CL_i

a_i → influence of CL_i on pollutant concentration

nCL_i → Corine Land Cover 2006 database + aggregation into 11 CL_i + integration of the road network class (vectorial geometry of national roads).

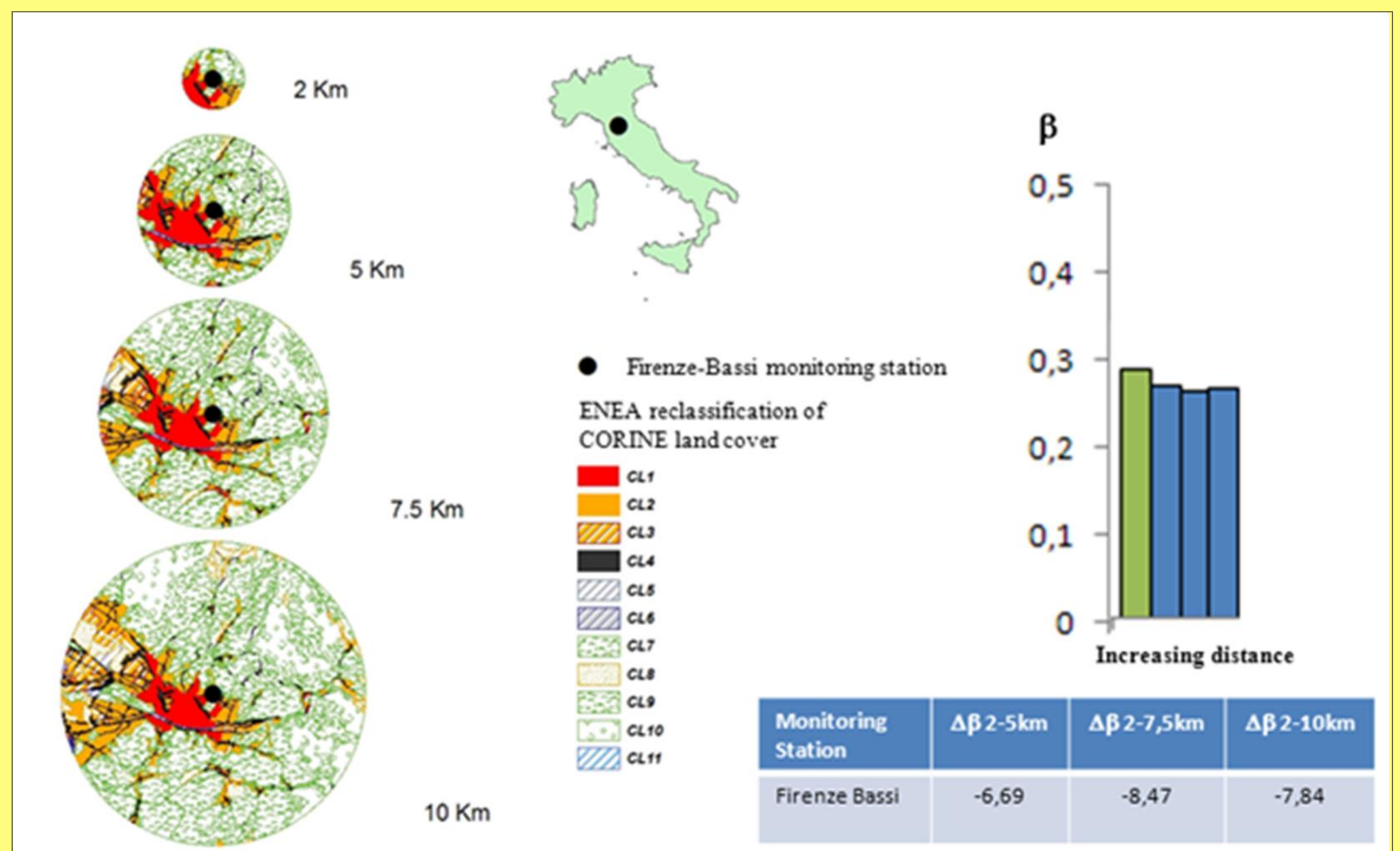
a_i → statistical optimization of the function $C(\beta)=n\beta^2+m\beta+q$, where C is the concentration. Multivariable regression on 2007 yearly average measured concentrations from the national database of air quality measurements.

Cases:

- 10 monitoring stations for PM2.5,
- 12 monitoring stations for O_3 or precursors,
- circular buffers with 2, 5, 7.5 and 10 km radius.

REPRESENTATIVENESS

The station is representative of an area included in a buffer if the value of β differs less than 20% from the value calculated in the 2 km buffer.



Monitoring Station	Δβ 2-5km	Δβ 2-7,5km	Δβ 2-10km
Firenze Bassi	-6,69	-8,47	-7,84

Fig. 2: Example of buffering for the 2, 5, 7.5 and 10 km radius, in the case of the Firenze-Bassi station for PM2.5, with calculation of β and evaluation of β variability with increasing radiuses.

METHOD 2: EMISSIONS VARIABILITY

CONCEPT

The principle is to define an inversely proportional relationship between emission variability around a monitoring site and its spatial representativeness.

PROCEDURE

We used, as a gridded emission inventory, a specific dataset produced by MINNI (2). Different time intervals for emission integration were tested (whole year, summer, winter), in order to capture the sensitivity to different patterns of polluting activities (domestic heating prevails in winter, road traffic and industry prevail in summer). The analyses were performed on primary pollutants (PM10, PM2.5, IPA, As, Cd, Ni, Hg).

REPRESENTATIVENESS

The evaluation of the representativeness is based on an automatic classification of range of values (natural breaks): **the approximate area of representativeness is in the two lightest colour ranges.**

With this definition urban stations have a low spatial representativeness due to the high variability of emissions in urban areas.

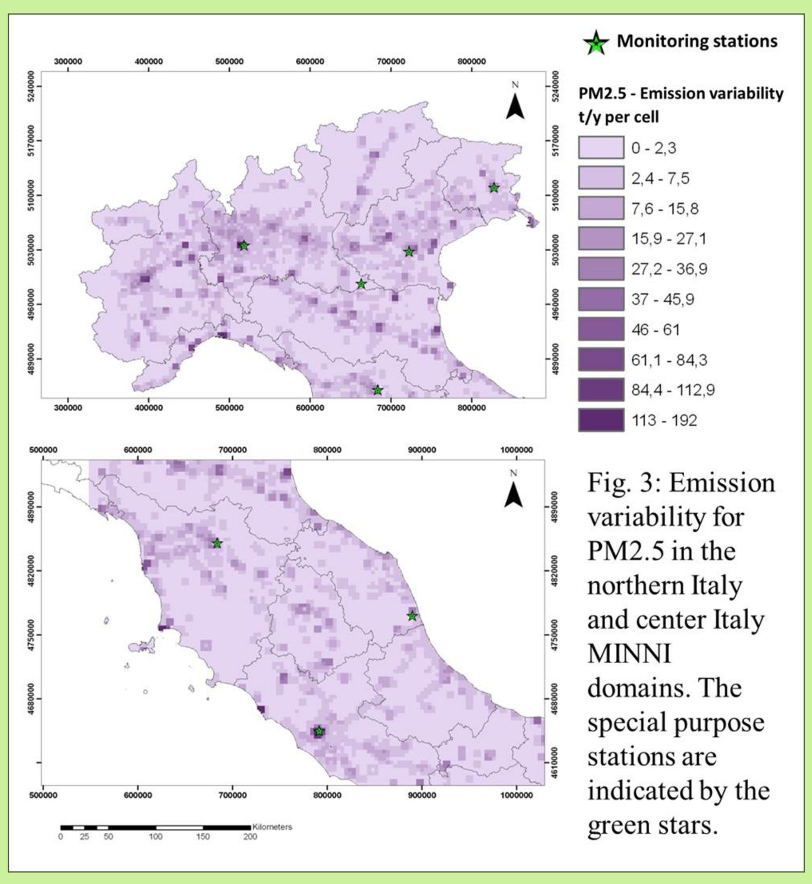


Fig. 3: Emission variability for PM2.5 in the northern Italy and center Italy MINNI domains. The special purpose stations are indicated by the green stars.

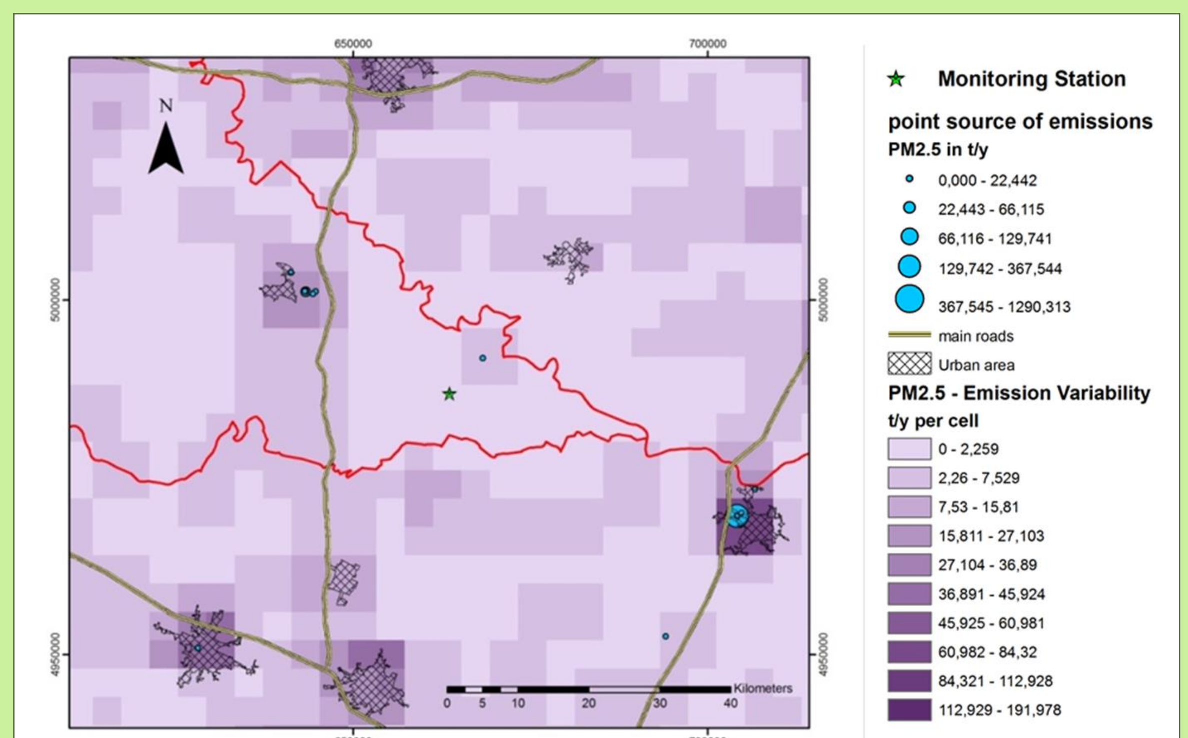


Fig. 4: Emission variability around Schivenoglia station (star in the center).

METHOD 3: CONCENTRATION SIMILARITY

CONCEPT

The concentrations recorded at the site of interest are directly compared with concentrations recorded at selected points in the surrounding area, in a fixed time interval.

PROCEDURE

As for method 2, we used the MINNI model dataset for concentration fields. At each time step, the difference between the concentrations modelled at the site of interest and at each grid point was calculated. A threshold value of 20% was set.

A 2-dimensional frequency function $f_{site}(x,y)$, specific of each site of interest, was used for counting positive occurrences of "concentration similarity" for each grid point of the model domain.

This procedure was applied on model results for PM10, PM2.5 and O_3.

REPRESENTATIVENESS

The monitoring station is representative of a wider area if the model values in this area differ by less than 20% threshold from the value at the station more than 90% of the times (3) (i.e. fsite(x,y) > 0.9 is verified).

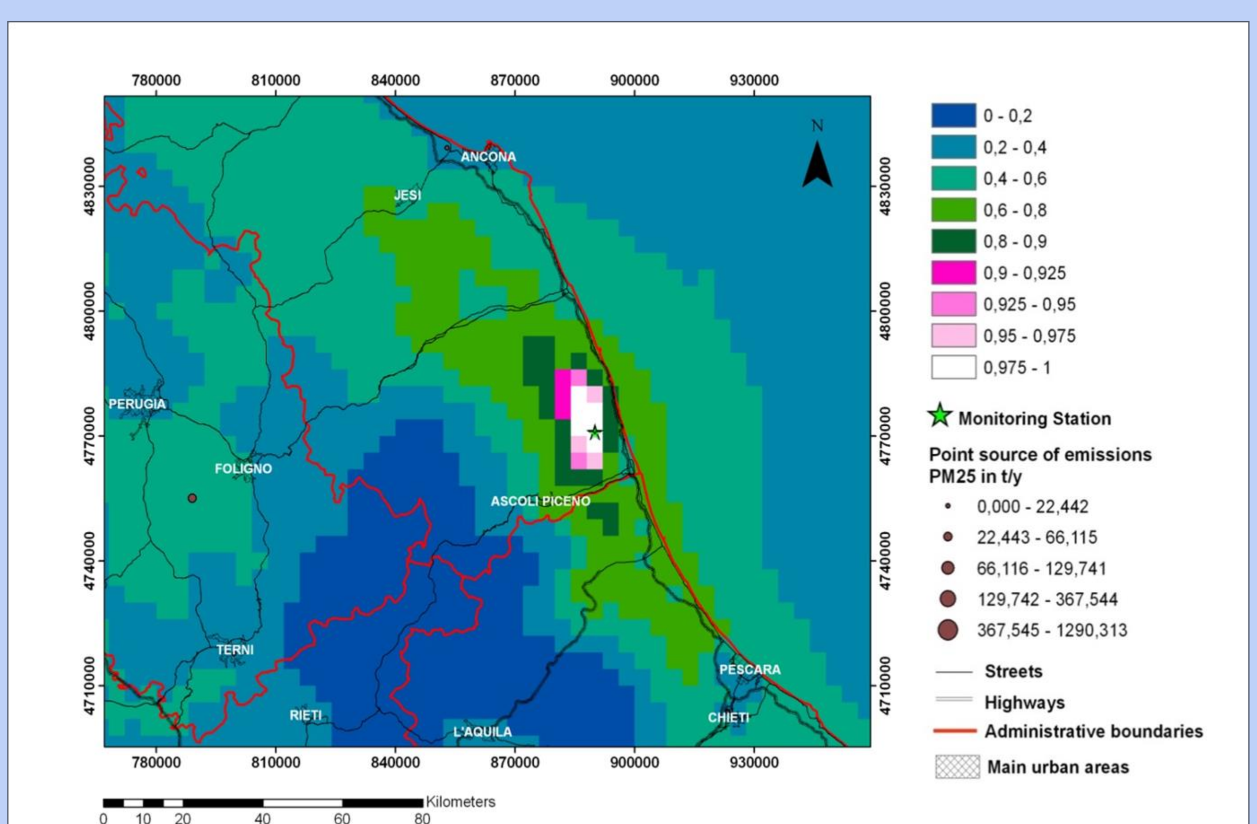


Fig. 5: Frequency function $f_{site}(x,y)$ for PM2.5 measurement at Ripatransone station. Representativeness area is in pink and white.

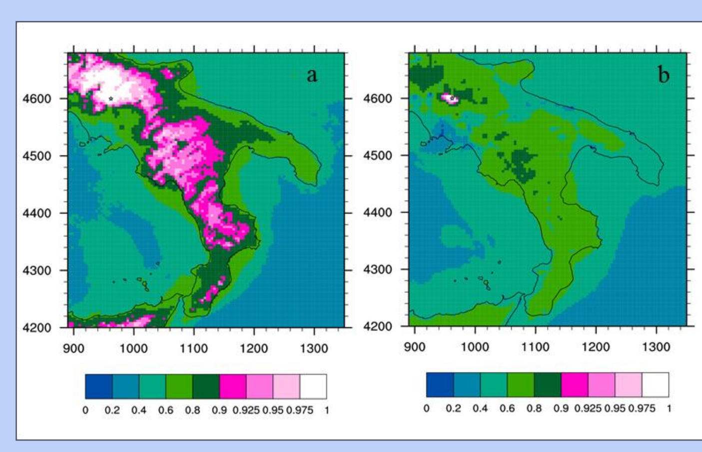


Fig. 6: Frequency function $f_{site}(x,y)$ for O3 at the Guardiaregia station using yearly series of daily maxima of running 8h-mean (a) and of hourly data (b).

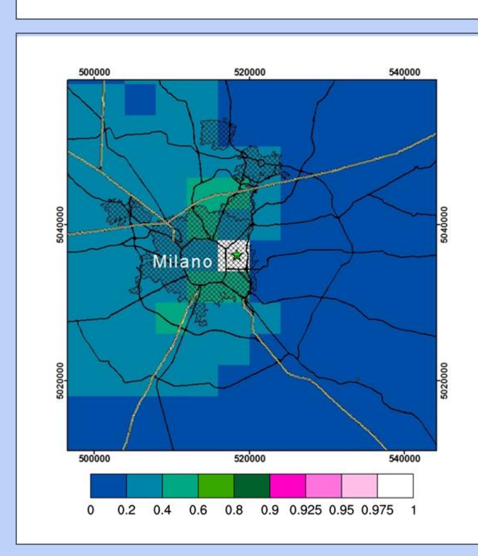


Fig. 7: Frequency function $f_{site}(x,y)$ for PM2.5 at the Milano Pascal station using yearly series of daily data. In this case as for other urban stations, the representativeness is not resolved due to model resolution.
Therefore this method is not suitable for evaluating the representativeness of urban stations at this scale.

CONCLUSIONS

For the implementation of the Italian Special Purpose Monitoring Network for air quality, ENEA has been testing different methodologies for the evaluation of spatial representativeness of monitoring stations, in order to study to what extent point measures at a single site represent pollutant concentrations in the surrounding area.

Method 1, based on land cover data as a proxy variable of concentration.

- The empirical relationship has a simplified formulation, therefore the quality of results strongly depends on the selected dataset of measured concentrations, used in the calibration stage.
- The method looks promising for evaluating urban monitoring sites, due to the free availability of high resolution datasets of land cover, describing accurately urban environments.

Method 2, MINNI gridded emission database to analyse emission variability as a proxy variable of concentration.

- Gives a complete picture of spatial variations of the polluting factor in analysis, covering the whole model domain, thus not depending on any monitoring site.
- This is useful for a comprehensive evaluation of spatial representativeness, even with some limitations (just primary pollutants, semi-quantitative evaluation).

Method 3, direct comparison of hourly concentrations at the selected site and in the surroundings by using MINNI gridded concentration database.

- The method proved to be particularly robust, as the comparison is performed at high time resolution and no proxy variable is used.
- Using a gridded model means that representativeness is evaluated at the spatial detail of the model grid, not allowing for example an adequate description of urban stations.

At present, a fourth method, based on backward trajectories of air masses reaching the selected site, is under development, relying on meteorology as a proxy variable of air pollution. The four methods will be applied to all stations of the Special Purpose Monitoring Network, to derive a final evaluation of spatial representativeness.

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